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Del S. Christensen

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	
Mark Wilson Anderson et al.	
Serial No. 10/621,631	Group Art Unit: NA
Filed July 17, 2003	Examiner: NA
JOINING EXPANDABLE TUBULARS	Date: February 16, 2004

COMMISSIONER FOR PATENTS
Alexandria, VA 22313-1450

Sir:

CLAIM TO PRIORITY

Applicant(s) reaffirm the claim for the benefit of filing date of the following foreign patent application referred to in Applicant's Declaration:

European Application Serial No. 02077905.4 filed July 17, 2002.

A copy of the application certified by the European Patent Office is enclosed.

Respectfully submitted,

MARK WILSON ANDERSON ET AL.

By _____
Attorney, Del S. Christensen
Registration No. 33,482
(713) 241-3997

P. O. Box 2463
Houston, Texas 77252-2463

Attachments

AMDS/TS6380 CTP

TS 6380 EPC

Europäisches Patentamt	European Patent Office	Office européen des brevets

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02077905.4

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02077905.4
Demande no:

Anmeldetag:
Date of filing: 17.07.02
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Anmelder/Applicant(s)/Demandeur(s):

SHELL INTERNATIONALE RESEARCH
MAATSCHAPPIJ B.V.
Carel van Bylandtlaan 30
2596 HR Den Haag
PAYS-BAS

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Joining expandable tubulars

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JOINING EXPANDABLE TUBULARS

Background of the Invention

The invention relates to a method of joining expandable tubulars.

Expandable tubulars are increasingly used in oil and gas production wells and may comprise slots or other perforations which are widened as a result of the expansion or may have a continuous 'un-slotted' wall which is circumferentially stretched by an expansion device such as an expansion cone and/or a set of rollers.

Expandable tubulars are generally joined by mechanical connectors since welding may create at least some strengthening and/or weakening of the pipe wall in the region of the weld, and strengthening will hamper or even disrupt the expansion process whereas weakening will result in a tube which will easily collapse, buckle and/or burst in the welding zone.

In addition, here it is required to weld slotted liners there are particular problems to overcome. In the first instance slotted expandable tubulars are difficult to seal completely to allow flushing with non-oxidising or reducing gases or gas mixtures and removal of air. In the second place welding the end of unprepared slotted liners will also cause the slots at the end of the tubular to be welded also. This impedes expansion and prevents proper functioning of the slotted expandable tubular.

It is known from International patent application WO 98/33619 to connect expandable tubulars by amorphous

bonding and from International patent application WO 0230611 to connect expandable tubulars by laser welding. However these connection techniques are time consuming and require a very precise positioning of the pipe ends relative to each other and machining the pipe ends into an extremely accurate flat shape that these technologies are not practical for use on for example a drilling rig, an offshore oil platform or pipe laying vessel.

It is an object of the present invention to provide a method of joining expandable tubulars by a relatively quick and simple welding operation, which can be carried out more easily on a drilling rig, offshore platform or pipe laying vessel than the prior art welding techniques and which generates a high quality weld that reduces variation of the pipe wall strength in the welding zone to a minimal level.

Summary of the Invention

The method according to the invention comprises joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the region of the forge welded tubular ends and the amount of irregularities between the forge welded tubular ends is limited.

The tubulars may comprise slots and/or other perforations at or near the forge welded ends, which slots and/or other perforations are filled with a heat resistant filler during the forge welding process.

Optionally, the tubular ends are heated by passing a high frequency current in circumferential direction through the tubular walls near the tubular ends that are to be joined, and the heat resistant filler comprises an

electrically conductive ceramic material. In addition, where it is desirable to provide a gas seal around the weld area to allow flushing with non-oxidising or reducing gas or gas mixtures extended internal and external sealing regions are required.

The tubular ends that are to be joined may both be expanded and folded into a substantially similar dented or corrugated shape before the forge welding operation, whereupon the dented or corrugated tubular ends are forge welded together and are unfolded into a substantially cylindrical shape during the subsequent tube expansion process. In such case the tubulars may have an un-slotted, substantially continuous, wall in the region of the welded ends and comprise an array of staggered slots and/or other perforations away of the welded ends, such that when the tube is expanded the welded initially dented or corrugated tubular ends unfold to a substantially cylindrical shape and the slots and/or other perforations are widened

The tubulars may be joined e.g. downhole in a well by forge welding after the expansion operation wherein the tubular ends are heated to a forge welding temperature and pressed together whilst a reducing flushing gas is flushed around the heated tubular ends during at least part of the forge welding operation. In such case the ends of the tubulars may at least partly overlap each other and a forge welding device is inserted into the inner tubular which heats up the tubular end, flushes a reducing flushing gas into any gap remaining between the overlapping tubular ends and which subsequently presses the outer surface of the heated end of the inner tubular against the inner surface of the outer tubular to join said tubular ends by forge welding.

Optionally, the tubular ends are teethed or have a complementary sinusoidal shape in order to alleviate forces to the forge welded tubular ends during the expansion and/or unfolding process.

It is preferred that the flushing gas is a non-explosive mixture of a substantially inert gas and a reducing gas, which mixture may comprise more than 90% by volume of a substantially inert gas, such as nitrogen, helium or argon and more than 2% by volume of hydrogen.

A large variety of heating technologies may be used to make the pipe ends hot enough such that the metallurgical bond can be made. The heating techniques may involve electric, electromagnetic, induction, infrared, arcing and/or friction heating or combinations of these and/or other heating methods.

When used in this specification the term forge welding is intended to encompass all techniques which involve circumferential heating of pipe ends and subsequent metallurgical bonding the heated pipe ends, including welding techniques that are generally known as fusion welding, friction welding, flash welding and/or butt welding.

It is known from US patents 4,566,625 ; 4,736,084 ; 4,669,650 and 5,721,413 issued to Per H. Moe that it may be beneficial to flush the pipe ends just before and during the forge welding operation with a reducing flushing gas, such as hydrogen or carbon monoxide, such that any oxygen skin is removed from the heated pipe ends and a metallurgical bond with a minimal amount of irregularities is obtained. It is also known from US patents 2,719,207 and 4,728,760 to use non explosive mixtures comprising about 95% by volume of a substantially insert gas, such as argon,

nitrogen and/or helium, and about 5% by volume of a reducing gas, such as hydrogen and/or carbon monoxide for flash welding and induction butt welding.

Description of preferred embodiments

A preferred embodiment of the method according to the invention will be described in more detail and by way of example with reference to the accompanying drawings, in which

Fig.1 depicts a partially longitudinal sectional and partially side view of a slotted tubular at the diameter after installation;

Fig.2 depicts a cross-sectional view of the tubular of Fig.1 after the tubular end is folded into a corrugated shape; and

Fig.3 is a side view of the tubular shown in Fig.2 showing the transition from the slotted mid section towards the corrugated end, which is subsequently forge welded to a corrugated end of an adjacent tubular.

Fig. 4 is an illustration of the steps required in an embodiment of a technique to ensure that the slots or perforations created in various expandable tubulars are filled with a refractory material to allow the pipe ends to be forge welded without the slots or perforations being welded together.

Fig. 5 depicts a seal assembly for forge welding of a slotted or perforated expandable tubular in which internal and external sealing areas have been significantly extended beyond that used for non-slotted and non-perforated tubulars

Expandable slotted tubulars as shown in Figures 1-5 are used in oil and gas wells to control e.g. sand production.

For this purpose the tubulars are wrapped with an assembly of screens with a specific mesh size to prevent sand from entering into the hole during production.

The tubulars with the screens wrapped around them are supplied to the well location in lengths of typically 10 m. The tubular sections are connected by slotted thread connections.

The slots in both parts of the thread connections are aligned and locked during make-up of the tubular on the rig. Once the tubular has reached its target depth in the hole it is expanded by pushing a cone through the tubular to ensure an intimate contact between the outer wall of the expanded tubular and the formation or casing inner wall.

The slotted connections are designed in such a way that the expansion force required at the cone to expand the connection is similar to that of the slotted pipe itself. This is essential because it enables the cone to be pushed down the hole without the risk of buckling the un-expanded pipe section below the cone.

However, the connections are expensive elements of the tubular and the make-up of the connections while running the tubular into the hole is a critical operation.

The forge welding method according to the invention aims at replacing of the threaded connection by a welded connection to overcome the disadvantages of the threaded connections. The method according to invention comprises a partially slotted tubular (1) as shown in Fig 1 , having a diameter D2 which is substantially similar to the diameter after expansion in the hole. The end faces (2) of the tubular are machined as per the requirements for the welding process to be applied on the

rig site. The middle section of the tubular (3) is provided with slots (4) leaving solid sections (5) of pipe at both ends of the tubular.

Fig: 2 shows the solid end section (5) which is folded in such a way that the outer diameter of the section equals the diameter D1 of the pipe while running into the hole.

After that the middle section (3) is also reduced to the same diameter D1 by compressing the slots machined in the pipe body which is shown in Fig: 3. This implies that the middle section remains cylindrical. Finally the tubular is provided with the screen assembly.

On the rig the corrugated end sections (5) of two tubular sections are welded together by applying the welding process e.g. the SAG-welding process. Once the pipe has reached the target depth a cone is pushed through the tubular from top to bottom. The slotted pipe body is expanded to its original diameter D2 and the corrugated end sections of the joints which are welded together are unfolded and reach their original diameter again.

Advantages of the welded connection are:

- Handling of the tubular joints on the rig site is drastically simplified because alignment of the tubular joints is easily done by aligning the corrugated end sections of the joints.
- The end sections of the joints are not slotted which facilitates the heating process; there is a continuous path for the current flow.

The cone force required to shape the solid end sections of the slotted tubulars is much lower than the force required to expand the section because the end

sections are only "unfolded"; no increase of the circumferential length of the tubular is required.

- A large diameter ratio between the tubular while running into the hole and after installation because this ratio is not limited by the maximum expansion ratio of solid tubulars.
- The diameter ratio is governed by the percentage of the circumference of the tubular that is provided with slots.

An alternative process and embodiment of the welded slotted tubular comprises a tubular with an initial diameter equal to that required for running the tubular into the hole. Both end sections of this solid tubular are expanded to the diameter of the tubular after installation in the well. The middle section and part of both expanded end sections are provided with slots. Then the expanded end sections (solid and slotted part) are folded to reduce their diameter again to that of the slotted part of the tubular.

After this, the procedure is identical to that described above. The limitation of this process is that the maximum diameter ratio between pre and post expansion that can be achieved is governed by the maximum expansion ratio of the solid pipe.

To prevent the slots or perforations which are a necessary element in a variety of expandable tubulars welding together during the forge weld process it is necessary to fill the slots or perforations with a non-weld-able material which will not interfere with the welding and expansion processes. Figure 4 illustrates the steps required to fill the slots or perforations with ceramic slurry that sets inside the slots or perforation. The first step in the operation, 6, indicates solid

tubular prepared for slotting or perforating. Slots or perforations are then cut, 7. In some variations of the technology slots and/or perforations are cut in sheet which is then worked into tubulars. It is the intention of this claim to cover both of these alternative methods of producing slotted/perforated expandable tubulars. For forge welding it is sometimes advantageous to increase the width of slots which intersect the free surface of the tube butt end for a distance of approximately 1 - 2mm from the butt end.. Once the slots or perforations are made a coffer is positioned around the ends of the tubulars and the area is flooded with ceramic slurry, 8. Vibration may be applied to ensure that the slurry completely fills the perforations or slots. It is necessary for the coffer to encompass an area of the tubular extending from above the tip of the tubular to a region covering at least two rows of perforations or slots. Typically this would require a depth of coverage of approximately 100mm. Finally, excess ceramic is removed, 9, leaving the slots or perforations completely filled.

During welding of the butted pipe ends it is often advantageous to flush the weld area with a reducing or non-oxidising gas or gas mixture. To accomplish this with slotted or perforated expandable tubulars it is necessary to ensure that the area containing the slots is completely sealed. Figure 5 illustrates a simple method to accomplish this. A sealing device, 12, is positioned inside the upper and lower pipes, 10. The sealing device sealing elements,13, are of a sufficient length to completely cover at least two rows of slots or perforations, 11. This configuration ensures that the internal area at the ends of the tubular is sealed to

allow gas flushing. In addition to the internal seal an external sealing chamber is also required, 15. This sealing chamber has extended sealing elements, 14, which are designed to completely cover at least two rows of slots or perforations.

The requirement to completely cover at least two rows of slots or perforations as described above is the preferred embodiment however where the slots or perforations do not overlap it is acceptable to cover only a single row, although this increases the risk of leakage.

C L A I M S

1. A method of joining expandable tubulars, the method comprising joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the forge welded tubular ends and the amount of irregularities between the forge welded tubular ends is limited.

2. The method of claim 1, wherein the tubulars comprise slots and/or other perforations at or near the forge welded ends, which slots and/or other perforations are filled with a heat resistant filler during the welding process.

3. The method of claim 2, wherein the tubular ends are heated by passing a high frequency current in circumferential direction through the tubular walls near the tubular ends that are to be joined, and the heat resistant filler comprises an electrically conductive ceramic material.

4. The method of claim 2 in which slots and/or perforations which intersect the exposed pipe tip are modified having an increased width at the pipe end to mitigate against forging together.

5. The method of claim 1, wherein the tubular ends are both expanded and folded into a substantially similar dented or corrugated shape before the forge welding operation, whereupon the dented or corrugated tubular ends are forge welded together and are unfolded into a substantially cylindrical shape during the subsequent tube expansion process.

6. The method of claim 5, wherein the tubulars have an un-slotted, substantially continuous, wall in the region of the welded ends and comprise an array of staggered slots and/or other perforations away of the welded ends, such that when the tube is expanded the welded initially dented or corrugated tubular ends unfold to a substantially cylindrical shape and the slots and/or other perforations are widened.

7. The method of claim 1, wherein the tubulars are joined by forge welding after the expansion operation and the tubular ends are heated to a forge welding temperature and pressed together whilst a reducing flushing gas is flushed around the heated tubular ends during at least part of the forge welding operation.

8. The method of claim 7, wherein the ends of the tubulars at least partly overlap each other and a forge welding device is inserted into the inner tubular which heats up the tubular end, flushes a reducing flushing gas into any gap remaining between the overlapping tubular ends and which subsequently presses the outer surface of the heated end of the inner tubular against the inner surface of the outer tubular to join said tubular ends by forge welding.

9. The method of any preceding claim, wherein the tubular ends are teethed or have a complementary sinusoidal shape in order to alleviate forces to the forge welded tubular ends during the expansion and/or unfolding process.

10. The method of any preceding claim, wherein the flushing gas is a non-explosive mixture of a substantially inert gas and a reducing gas.

11. The method of claim 10, wherein the flushing gas comprises more than 90% by volume of a substantially

inert gas, such as nitrogen, helium or argon and more than 2% by volume of hydrogen.

A B S T R A C T

JOINING EXPANDABLE TUBULARS

A method of joining expandable tubulars comprises joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the forge welded tubular ends and the amount of irregularities between the forge welded tubular ends is limited.

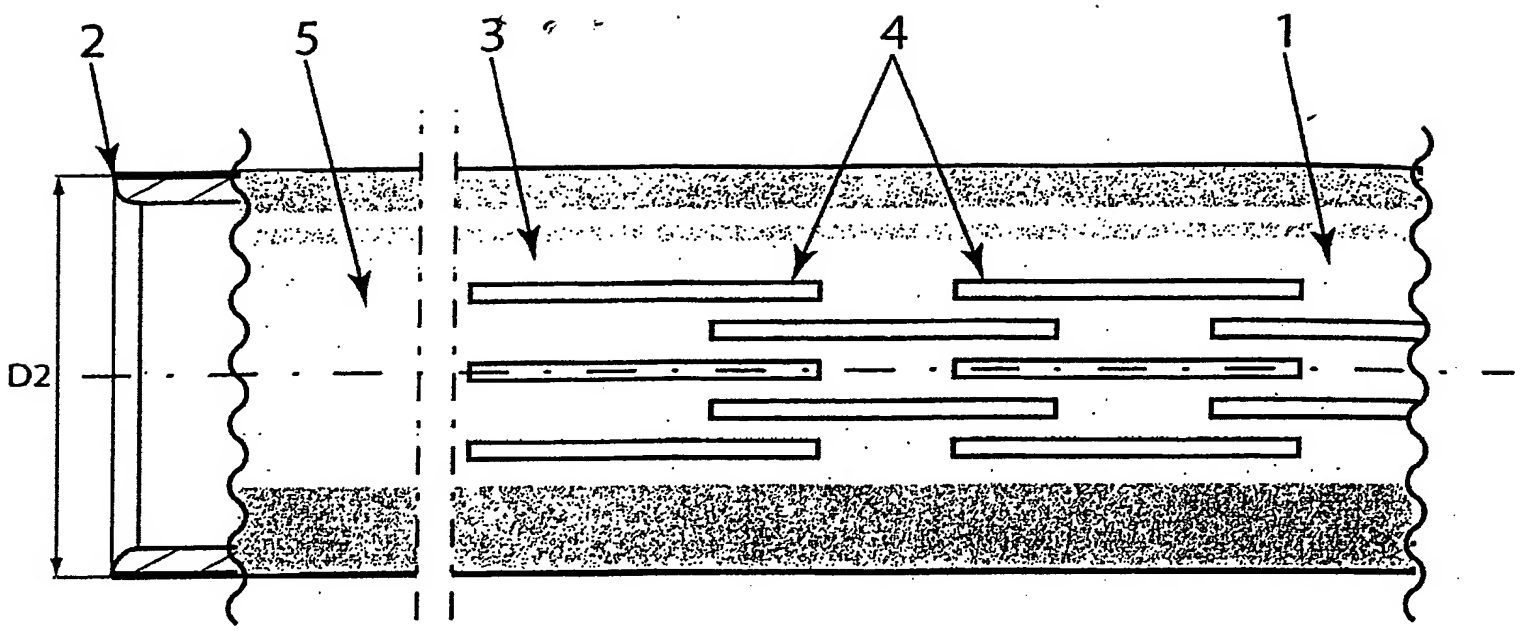

Fig. 1 Tubular with end faces and slots machined.

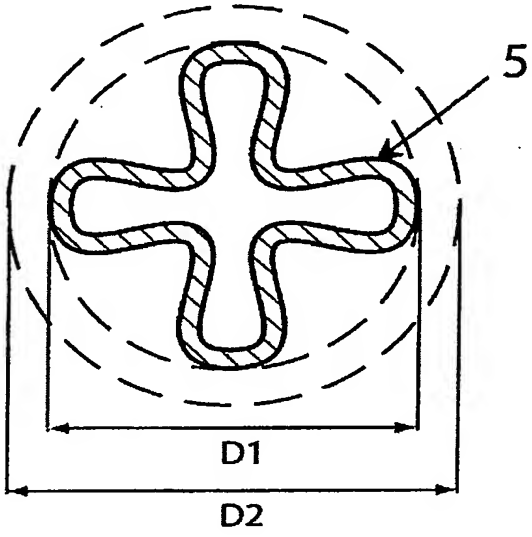

Fig. 2 Solid end face corrugated to diameter D1.

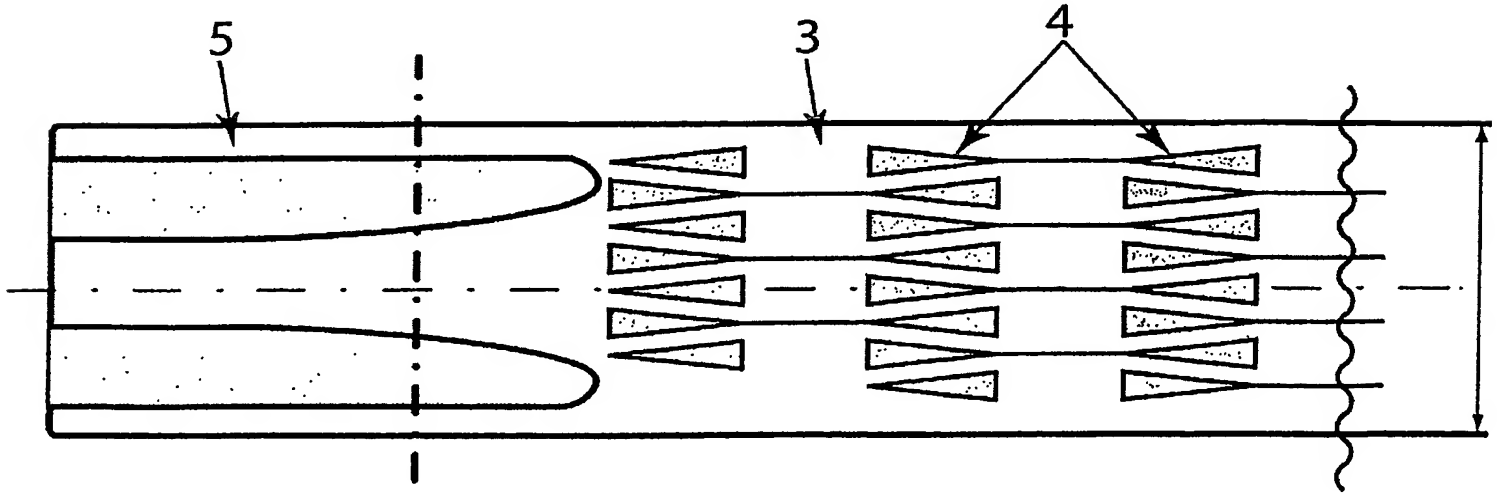

Fig. 3 Tubular with slotted section compressed to diameter D1

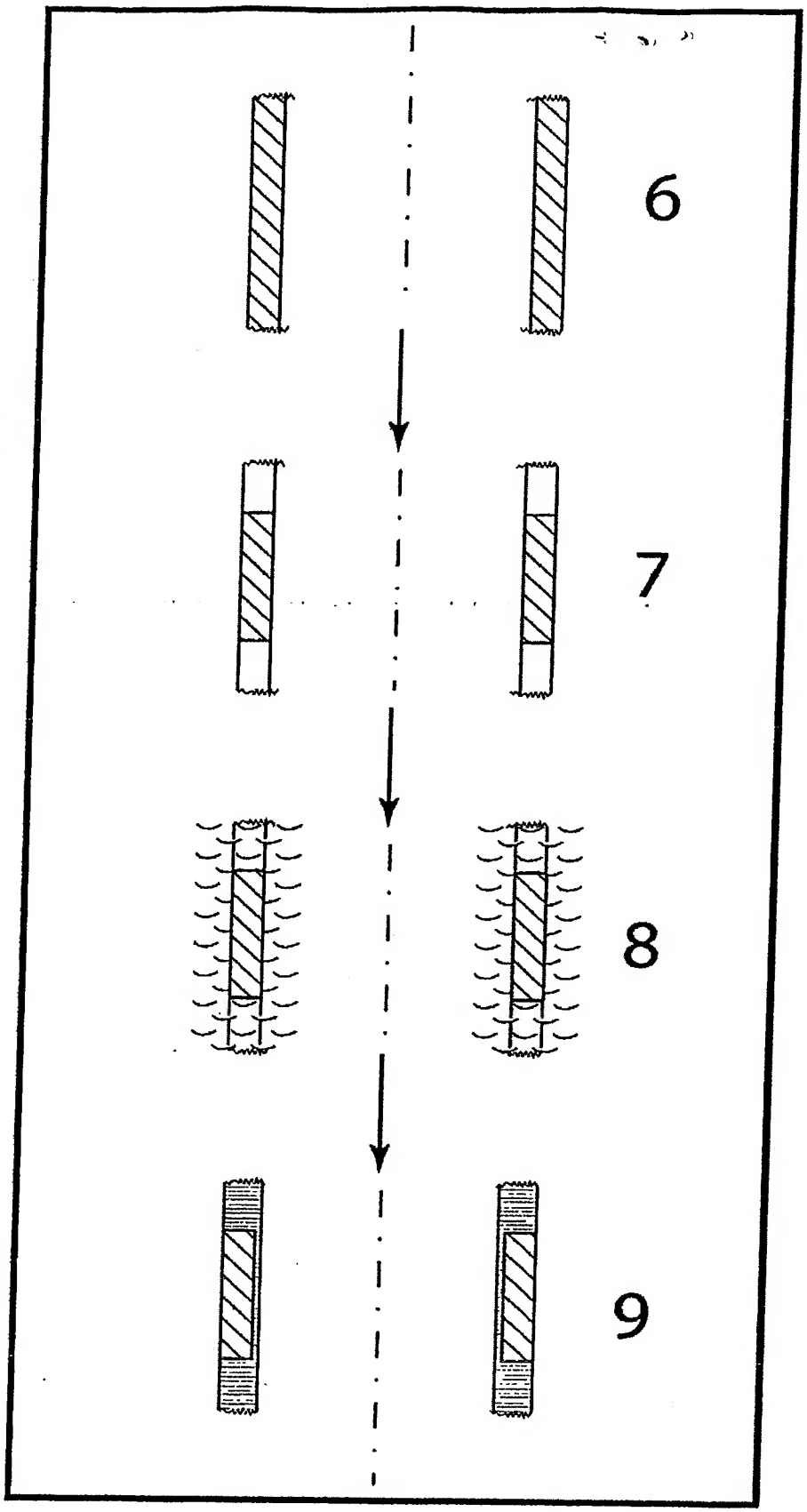

Figure 4 End section of expandable slotted tubular with slots filled with ceramics.

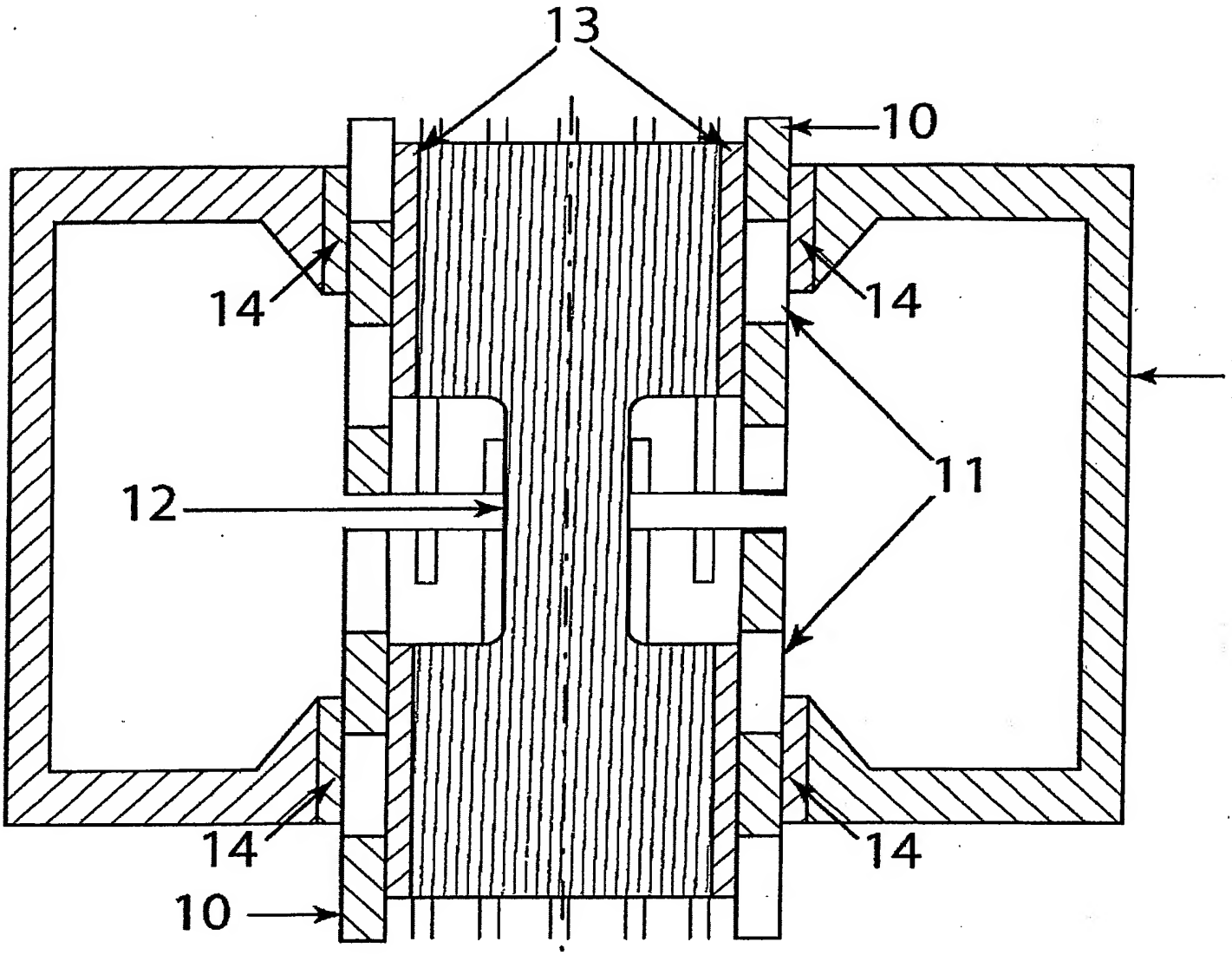

Fig. 5 Seal assembly for forge welding of a slotted expandable tubular.